Properties of ion trapping measured by the SCRI LMon

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The SCRI detector is composed of a Window-frame Spectrometer for Electron Scattering (WISER) to measure the angular distribution of scattered electrons1) and a Luminosity Monitor (LMon) to measure the absolute luminosity of electron-RI scatterings.2) LMon is measuring the bremsstrahlung photons and determine the luminosity as $L = N_{br}/t\sigma_{br}\epsilon$ (cm$^{-2}$s$^{-1}$), where $N_{br}/t$ is the number of bremsstrahlung photons per second, $\sigma_{br}$ is the bremsstrahlung cross-section, and $\epsilon$ is the detector acceptance. $\sigma_{br}$ can be calculated using a theoretical model3),4) and LMon consists of two main components to measure the remaining factors: a CsI calorimeter to measure $N_{br}/t$ and a two-dimensional fiber scintillator detector to measure the spatial distribution of bremsstrahlung photons which have to be compared with GEANT4 to determine $\epsilon$. The first physics experiment using $^{132}$Xe and $^{208}$Pb targets was performed in 2015-2016. Results of the experiment using WISER are reported elsewhere,3) and progress on LMon with respect to the determination of $\epsilon$ and its uncertainty is described in a separate report.5)

In this article, detailed measurements of ion trapping by LMon using $^{132}$Xe data are reported.

With a recent upgrade of LMon, it has acquired the ability to measure $N_{br}$ as a function of trapping-time, which revealed detailed properties of the ion trapping. Figure 1 shows $N_{br}$ as a function of the trapping-time measured at an electron beam energy ($E_{e}$) of 150 MeV for different beam currents. Here IonIN and IonOUT denote measurements with and without trapped $^{132}$Xe ions, respectively. That is, IonOUT is the background contribution from residual gases (e.g. H$_2$, O$_2$), and the net amount of $N_{br}$ from $^{132}$Xe ions is estimated as IonIN-OUT. The IonIN-OUT decreases as a function of the trapping-time, implying that trapped target $^{132}$Xe ions are depleted with time. On the other hand, the number of trapped residual gas ions, which is shown by IonOUT, can be increased as a function of the trapping-time since there are virtually infinite neutral residual gas atoms inside the chamber, which are continuously ionized by the electron beam and trapped by the SCRI device. Figure 2 shows the $N_{br}/t$ of IonIN-OUT as a function of the trapping-time for several currents and beam energies. $N_{br}/t$ increases as the electron beam current/energy increases, which can be naturally explained by the fact that the beam density increases with increasing beam current/energy. It is interesting to note that there are fast and slow components in the trapping-time dependence, and the slow component becomes prominent as the beam energy and/or current increases. A feasible explanation is that the slow component originates from high-charged-state nuclei, which increase at time scales on the order of hundreds of milliseconds.

In summary, the properties of ion trapping at the SCRI experiment have been measured by LMon. This information is useful for tuning the electron beam and SCRI device parameters to optimize the ion trapping and maximize the luminosity, even though more detailed studies using simulations and calculations are required to reproduce the observation.

![Fig. 1. Trapping-time dependence of $N_{br}$ measured for different beam currents for $^{132}$Xe at $E_{e} = 150$ MeV.](image)

![Fig. 2. Trapping-time dependence of $N_{br}/t$ measured for different beam currents and energy regions.](image)

References
3) Y. S. Tsai, Rev. Mod. Phys. 46, 815 (1974).
4) K. Tsukada et al., in this report.
5) T. Fujita et al., in this report.

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